# MISCELLANEOUS NOTES ON AUSTRALIAN DIPTERA. V.

## ON EYE-COLORATION, AND OTHER NOTES.

By G. H. Hardy.

(One Text-figure.)

[Read 26th April, 1939.]

*A theory of the Eye-marking.*—David Sharp (*Cambridge Natural History*, vi, part 2, 1899, p. 440), referring to eye marks on living flies, states that it is uncertain what use the variegated eye-coloration may have; subsequent authors seem to have limited their interests, in print, to the needs of taxonomy, and they figure markings more effectively than they describe them. There does not seem to be any plan upon which a uniform system of descriptions can be based. Enough, however, has been published to indicate that eye-marking is a phenomenon in the evolutionary process of the insect.

Probably the primitive eye-colour is black; this is common in the Nematocera, but limited to the lowest section in the Brachycera, where black is rarely found. The first advance is indicated by the possession of red eyes, a common feature throughout the Brachycera, with other hues, which may partly or completely cover the eye. The variegated colour pattern so frequently found seems always to be based on a red eye, and is never found on the primitive black eye.

The most advanced eye is normally green, rarely yellow, blue, or some other colour, and it is the change from the red to green that is considered here.

The change takes place in two ways. In some cases the green invades the red uniformly so that there first appears the red eye with green reflections, changing to red and green equally reflected, then green with red reflections, and finally the eye becomes wholly green. The other method is a change through the colour-band development, an account of which is given below. Actually several large genera show a range from a species with red eyes, through species with the red invaded with green to varying degrees, to a species with entirely green eyes. The variegated eyes can be arranged in a series to show how the change proceeded, and this seems to follow a uniform plan for all genera, but varies in the details with each genus.

The consistency of marking retained by each species suggests that some slight change in structure within the eye may take place uniformly with the change in colour; thus there are produced the marked contours that vary very little on any one species, although some variation in actual colour is not unusual.

I make no attempt to explain why colour changes should proceed through the colour-band system, but it seems advisable to point out that perhaps vision given by black eyes is less efficient than that by red eyes, whilst the green may be much superior to both; even a small area of green in a red field may be advantageous. Entirely green eyes occur consistently throughout the Asilidae and are common in many other predaceous Brachycera, whilst blood-sucking forms

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have both red and green, as well as the variegated eyes. Black eyes occur rarely in Stratiomyiidae, but apparently always in Cyrtidae, and perhaps in most Conopidae. Exotic Leptidae are often recorded with green eyes, but in the Australian species the eyes always seem to be red.

*The theory of colour-band development.*—By simplifying the complexities seen in colour marks, it becomes apparent that there first develops a green spot which extends laterally across the red field at antennal level, and lying in band formation practically parallel with the central line of the insect from head to abdomen, no matter what this direction may be in relation to the major axis of the eye. The band of green becomes complete when it reaches the anterior and posterior eye-margins. Above and below the green band so formed, the red areas of the eye form two blotches touching respectively the upper and the lower eye-margins and in either or both of these, further green spots form, running to bands parallel to the original one. By this process red bands are isolated; the blotches which still retain contact with the eye-margins above and below become smaller in area, and between them now lie alternating green and red bands.

Complications are introduced by the green having a tendency to spread, upsetting the band formation by invading the red areas in another way. In the lower Brachycera, this takes place largely by the green invading along the eye-margin, and in the higher Brachycera the invasion is strongly marked in the central field of the eye. It is also quite normal to see this spread more pronounced over the lower half of the eye than the upper half. The green thus encroaches over the red areas until the bands and blotches disappear. There is no uniformity in this matter; many species have eye-markings which may be used with conspicuous success in specific determinations, and any large genus may exhibit grades in markings, all being of the one general type.

Eye-coloration and markings may take some other form, as in Syrphidae, where some unusually active *Eristalis* have yellow eyes with minute black spots that survive death, but the chief interest lies in the colour-band type found in the following families: Stratiomyiidae, Tabanidae and Therevidae (colour band range very wide), Syrphidae (colour band at least in genus *Bacchus*), Ortalidae (colour band plentiful, but not studied in detail), and Calliphoridae (colour band limited to Rhiniinae).

*A Scheme for Describing Eye-markings.*

1. *The primary green band.*—All marks are orientated about that green band which forms the original invasion of the red eye and is situated at antennal level. It is to be noted that the area at antennal level is almost invariably green at least in part. This colour may extend indefinitely above and below, the nature of the band thus becoming lost in the general green field on species with advanced eye marks.

2. *The red bands.*—With the development of additional green bands above and below the primary one, red bands are left between them. Thus one red band lies just above, another just below the primary green band; rarely do either of these red bands lie in a position that can be confused with the antennal level.

3. *The multiplicity of bands.*—Further green bands may develop above and below, leaving red bands between them. This division of the red area may develop until seven green and six red bands are present, these being the maximum numbers of true bands observed in Diptera, although the green may spread along the eye-margins (as in some Rhiniinae), making the remnant of the original red blotch at the upper and lower eye-margins resemble a further band of red.

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4. *The blotches.*—With the formation of the primary band, there are left two red areas retaining contact with the upper and lower eye-margins respectively. These two portions of red are the blotches, and they become smaller with every successive increase in the number of bands formed in the red areas. If perchance the green colour isolates the blotch from contact with the eye-margin, then the area of red left becomes a spot and the term blotch will no longer apply.

5. *The spots.*—This may apply either to the red or the green areas that do not touch the eye-margins and that are sufficiently spot-like to warrant the term.

6. *Colour invasion and elimination.*—Together with the tendency to build up the eye-markings to a maximum number of green and red bands, there is also a tendency for the green to invade and eliminate the bands formed and blotches left. This extra invasion by the green mostly takes place along the eye-margin in the lower Brachycera and largely in the central area in the higher Brachycera. In this way there is a trend towards the production of two markedly distinct eye-patterns, both traceable to band formations when analysed. The red colour disappears by suppression and the green increases by invasion and by the fusion of one green area with another. For descriptive purposes, when bands and blotches have been enumerated relative to antennal level, then this further invasion of green, bringing distortions and alterations in the red areas, is described only when marked effects are present.

7. *Abortive band development.*—It sometimes happens that the eye-marks show an abortive development, as in the case of *Wallacea.* Here the band at antennal level does not develop, but remains as a small elongate spot in a field of red, and above it in the same field are two other small elongate spots of green. This has produced an apparent blotch containing markings within, but on analysis with regard to antennal level they are readily interpreted. There are other abnormal markings which need to be interpreted in another way.

8. *Abnormal band development.*—That the simple horizontal band development does not apply in all cases is well illustrated in the case of some exotic Tabanidae, but is not yet known in the Australian fauna. In the genus *Chrysops* studied in the Palaearctic and the two American regions, the band development is vertical and irregular in shape; the blotches lie along the anterior and posterior eye-margins when present. Further invasion by the green takes place along the eye-margins and the red bars give way to spots that retain strong traces of their original irregularity. The genus *Chrysops* has its antennae placed near the eye-centre level, but *Tabanus* has the antennae nearly level with the lower eye-margin, and it is interesting to note the angle in these two cases; the line between the eye-centre and antennae compared with the direction of the eye-bands is about the same.

9. *Variations in colour.*—In the eye-colour the green and the red are not necessarily constant. Blue and purple may develop in their place, or an area may be bordered with these colours, and more rarely the green may give place to yellow. Melanism may appear in the eye, or at least a deepening of the shade resembling black may give this effect, but the actual markings seem nearly always to remain constant for each species.

10. *Irregularities in bands and blotches.*—Bands may disappear by elimination of the red and fusion of the green; they may reach the eye-border or fail to do so; the size of the blotches may depend on the number of bands formed, all lending themselves to description in general terms in conformity with the present discussion. In addition, markings are frequently different in the sexes, but usually

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### Stratiomyiidae.

### Neoexaireta spinigera Wiedemann.

In life the eyes are entirely black and the habits are striking when regarded in this light, for the fly is particularly active and wary of movements so as to be not readily caught. It breeds in piles of decayed vegetation in gardens and orchards, where it mostly abounds, and is often abundant around sheds; it rarely enters houses, apparently avoiding dark places. The fly is very rapid in flight and has quick dodging movements.

### Actina brisbanensis, n. sp.

*Actina incisuralis* (dark form), Hardy, *Proc. Roy. Soc. Queensland*, xliii, 1932, 53.

The exact identity of *Actina incisuralis* is uncertain; it is regarded as being that form most commonly met with in Sydney, but owing to variations found in collections there would appear to be several forms already discussed by me. This *incisuralis* group, which includes the Tasmanian form as a possible subspecies, becomes difficult to unravel. Possibly more than one species occurs in Tasmania and certainly two occur in Queensland; the one described here is not known to me outside this State with certainty, but is very common at times in Brisbane, where it would seem to be the only species occurring.

The other Queensland species, still regarded as being *incisuralis*, has on the female a red band at one-quarter of the eye-depth from the summit in a green field and stretching from the anterior margin three-quarters of the way towards the posterior margin, which marking differs from the present species considerably.

♂, ♀. Very like *A. incisuralis* Macq., but the black markings on the tergites are invariably broadly black, thus reducing the orange colour, which may be entirely eliminated in the case of the male. The orange colour varies in amount, but never seems to increase in size comparable with that of the other various forms of *incisuralis* seen. The eyes on both sexes have the red and green intermingling with shot effect in more or less equal amounts, and there is no trace of a marking in the eye.

*Hab.*—A very long series taken in Brisbane over many years, throughout the summer half of the year; it seems quite common in the autumn on the underside of the leaves of the Moreton Bay Fig trees in the Botanical Gardens and University grounds.

### Lecomyia cyanea White.

At the time of capture (10.10.1923), I made a sketch of the eye-marks on this species, and this shows a blue-green field with a red band above antennal level, strongly angulated near, but not reaching, the posterior margin. This is the effect of a sudden broadening of the band just before terminating; the narrowest part is about the centre. The green band above is thus very irregular in shape and fuses along the posterior eye-border with the green covering the eye below the red band. The upper red blotch reaches about half the length of the frons.

A pair of these rather rare flies recently captured (Sunnybank, October, 1938) shows a normal green field on both sexes and, instead of the upper blotch, a second red band which slopes about 45 degrees upwards from the middle of the frons,

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### Genus Damaromyia Kertesz.

Hardy, *Ann. Mag. Nat. Hist.*, (10) viii, 1931, 120–8.

*D. whitei* Hardy has the eyes green with a red band just above antennal level, and the band curves upwards posteriorly, but does not reach the posterior eye-margin. *D. clivosa* Hardy has a green band at antennal level between a red band below and a red blotch above; below this the eye is green. A sketch pinned with the specimen shows the blotch has a sinuous lower border, making the green band irregular in depth.

Two new species described below run out at couplet 5 of my key which can be used here by substituting the following new rendering of couplet 5 and adding the couplets 12 and 13:

5. Frons with a median deep depression; frons one-fifth to one-sixth head-width .. 6
   Frons without the depression; scutellum with one marginal depression ..... 12
12. Hair-pits plentiful on frons and with the hairs abnormally long there; body hairs also much more conspicuous than normal. Frons one-quarter the head-width ..... *hirsuta* Hardy
   Hair-pits and hairs normal ..... 13
13. Frons one-quarter the head-width ..... *neohirsuta*, n. sp.
   Frons one-sixth the head-width ..... *similis*, n. sp.

*D. neohirsuta* is one of the two species recorded by me as near *D. hirsuta*; the other referred to is in the Ferguson collection and from Sydney; no further specimens have come before me. *D. similis* is quite a new form and both sexes are known.

### Damaromyia similis, n. sp.

♀. Frons converging towards antennae, median width one-sixth that of the head. The hair-pits are arranged two together each side of the ocellar triangle and increase to three in a diagonal row towards the antennae; these lie mostly in a long slight depression each side of the very narrow grooved carina. The eyes in life are red shot with green and the eye-frons-eye proportions are 15:6:15. The thorax, scutellum and abdomen dorsally are completely covered with punctures uniformly dense and the triangular scutellum, lying in a plane with the thorax, has but one marginal depression. The coxae are black, the remainder of the legs is yellow, usually fuscated centrally on the femora and tibiae.

♂. Body characters very much as in the female, with occasional small areas on which the punctures may be less dense. The eyes are contiguous, with the lower third (antennal level and below) green in life, the remainder red.

Variations from this normal do not seem to occur, and although there is a general depression each side of the carina, this may be due to shrinkage after death and is not to be confused with those deep depressions on the lower section of the frons and seen on other species. Those species having the frons one-sixth the head-width or near are distinguished by the presence of the depression and in additional characters; *confusa* has two marginal scutellar depressions, *tasmanica* has a parallel-sided frons, *whitei* has a distinctive eye-mark when alive,

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and *trina* is less regularly pitted on the body. The raised scutellum distinguishes *recemipuncta*, the only other species with a narrow frons and also without the deep frontal depression.

*Hab.*—Queensland: Brisbane, September and October, 1932 to 1937, mostly in the latter year. 10 ♂, 18 ♀ from a persimmon tree and nearby foliage in my garden at Sunnybank. I have no hesitation in relegating the male to this position, as the only other species taken was represented by two females referred to below and apparently were stray visitors, and not breeding in the locality.

### Damaromyia neohirsuta, n. sp.

♀. Very like *D. similis*, but differing by the frons being one-fourth head-width, with coarser punctures more generally distributed, reaching nearer the eyes over most of the length, and there are four punctures in a diagonal line anteriorly. The eyes, when alive, have the lower quarter green, the remainder red. The eye-frons-eye proportions are 9:6:9. The abdomen also differs in the punctures being less dense than on the thorax and scutellum; on the two latter they are as on *D. similis*. The male is not known.

The female is liable to be confused only with *D. hirsuta* because the characters on other known species with a wide frons differ in many ways, but *hirsuta* differs in having a greater density of hair-pits from head to scutellum and very conspicuous hairs; the hair-pits of the frons are too dense for the regular rows to be seen.

*Hab.*—Queensland: Brisbane, September, 1937, 2 females taken on a persimmon tree in my garden at Sunnybank, and in company with *D. similis*. Another female (now without a head) was taken in September, 1929.

### Wallacea splendens Hardy.

In both sexes the eyes are green, with a large apparent, rounded, red blotch on the upper third. As the antennae are situated very high on the head, the blotch descends below the antennal level, where, within the blotch, a short green band occurs. This band tapers to its ends, and above it is another band which widens at the ends, but is hardly longer, and again above these is yet a third green band that resembles the first. These green bands and the red blotch are all subject to colour variation, peacock-blue, purple, etc., being substituted. Apparently the species is not uncommon at Sunnybank, as students have collected a series, now in the Queensland University, and I myself have added more to my collection.

### Ophiodesma innodus Hardy.

A sketch that I made some years ago shows that the female of this species has a green band at antennal level, bordered above and below with a red-purple band, the upper one being the shorter, but neither reaches the posterior eye-border, nor does the next red band above, which resembles in general proportions the lowest of these three. The two intervening green bands are thus fused with each other along the posterior eye-margin and also with the green broad areas above and below the three central red bands. The lower of these green areas is exceptionally wide and fuses with yet another green band, along the anterior eye-margin this time, that lies between the outer red curved band and the blotch. Similarly these red and green bands are repeated in general shape and contour just below the red blotch at the upper eye-margin. Hence there are, in a green field, three central red bands that fail to reach the posterior eye-margin,

and *trina* is less regularly pitted on the body. The raised scutellum distinguishes *recemipuncta*, the only other species with a narrow frons and also without the deep frontal depression.

*Hab.*—Queensland: Brisbane, September and October, 1932 to 1937, mostly in the latter year. 10 ♂, 18 ♀ from a persimmon tree and nearby foliage in my garden at Sunnybank. I have no hesitation in relegating the male to this position, as the only other species taken was represented by two females referred to below and apparently were stray visitors, and not breeding in the locality.

### Damaromyia neohirsuta, n. sp.

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whilst above and below these respectively, there is another red band that fails to reach the anterior eye-margin, and also the two blotches. This makes two red blotches and five red bands alternating with six green bands, one of which is very wide. It will be noted that this is only one red and one green band less than the maximum yet noted in Diptera, and possibly a red band has disappeared from the very wide green area in the lower half of the eye. This forms the most complete example of retained eye bands I have yet noted in the Stratiomyiidae, but none of the red bands are complete, nor are any quite regular. The central red band is slightly curved and is the narrowest, the adjacent ones above and below expand towards the rear and only the lower of these two is reasonably straight. The other two bands, adjacent to the blotches, are strongly curved, one upwards, the lower one downwards following the contour of the equal blotches. The symmetry of the markings is very striking.

## Tabanidae.

### Genus Pelecorrhynchus Macq.

Two species, *P. personatus* Walk. and *P. fergusoni*, n. sp., definitely have entirely red eyes, which character I believe to be consistent throughout the genus.

#### *Pelecorrhynchus fusconiger*-group.

In the first part of this series I defined three groups within the genus, of which the present one is the second, containing five described species and several undescribed.

*Distribution.*—Only one species occurs in Tasmania and this, *fusconiger* Walker, extends as a coastal species at least as far north as Sydney. The more northern coastal species, *fergusoni*, seems to have a very limited range from the Brisbane area and Stradbroke Island and possibly the northern parts of New South Wales. Of these two, only the former reaches the mountain areas where all the other known species occur, some showing a limited range even there. It is to be particularly noted that the group is unknown from the Tasmanian mountains.

*Key to species of the* fusconiger *group.*

1. Wings with two contrasting colours; black and yellow ..... 2
   Wings unicoloured, more or less hyaline ..... 3
2. Thorax mainly yellow with a thin median black stripe ..... *deuqueti* Hardy
   Thorax mainly black with a pair of yellow stripes ..... *flavipennis* Ferguson
3. With some dense white pubescence at base of abdomen. Thorax mainly black with a pair of very broad, narrowly separated grey stripes, within each of which occurs a short black stripe near the scutellum. The grey stripe is bordered laterally with a thin whitish line ..... *tillyardi* Taylor
   White pubescence at base of abdomen if present sparse and the thorax otherwise marked ..... 4
4. Species with some fiery red hairs on thorax and abdomen ..... *claripennis* Ricardo
   Species without red hairs ..... 5
5. Thorax black with a pair of very thin whitish stripes interrupted just behind the transverse suture, and broadening out to meet along the apical margin. (From Barrington Tops.) ..... sp.
   Thorax brown or slate-greyish. The white stripes are complete or incomplete, but do not meet ..... 6
6. Thorax velvet-brown throughout with the whitish stripes conspicuous, at most, before the transverse suture and faintly indicated beyond this; often limited to a spot at the transverse suture. Rarely do black marks appear ..... ..... *fusconiger* Walk.
   Thorax more or less strongly slate-grey coloured with a conspicuous pair of whitish stripes complete and partly bordered laterally with thin black marks. There may also be a thin median black stripe ..... *fergusoni*, n. sp.

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*P. fusconiger* of authors in part.—Ferguson, *Proc. Roy. Soc. Victoria*, xxxiii, 1921, 2 (Queensland variety only).

Ricardo (1910) refers to *fusconiger* as occurring between Sydney and Moreton Bay, but specimens from the latter locality should be referred here. Taylor (1917) gives Stradbroke Island, and again all those specimens belong here. Ferguson (1921) records differences in the Stradbroke Island specimens, but did not regard the characters as more than a local variety at the time. Subsequently Mackerras has shown (but not published) that specific differences occur in the terminalia, and I have mounts of these made by him. Ferguson's description and the characters given in the key above are ample for the recognition of this species.

*Hab.*—Brisbane, August to October, 1924 to 1937, at the Sunnybank swamps. Also Stradbroke Is., from which many specimens come, as far as I know, all captured in September.

The flies do not seem to occur on the wing in any year for longer than a fortnight or three weeks, usually about the middle of September, varying with the early and late seasons. During 1937, a drought year, they appeared first in late August, then disappeared, but came again in very late September and early October. Similarly, *P. personatus* Walker, which normally comes in late September, became plentiful on the same swamps in October only. These are the only two species of the genus known to occur in the Brisbane district.

### Scaptia (Diatomineura) pulchra Ricardo.

On the female a red narrow band occurs well above antennal level, about half eye-depth; the area above this is blackish, and below it green. These colour marks are based upon a small series from Mt. Glorious, Brisbane.

### Scaptia (Diatomineura) auriflua Don.

On the female a blue blotch margined below with red extends from the summit to about two-thirds the distance towards the anterior eye-corners, and below this the eye is mainly green, but the blue extends along the posterior margin and peters out at the lowermost point of the eye. The description is from Brisbane specimens.

### Ectinopsis vulpecuna Wied.

In literature two varieties are recorded and the exact determination of them is not clear to me. On the Brisbane form the eyes of the male are green with a thin red band about antennal level, tapering to a point and not reaching the posterior border. This red marking is broader but similar on the female and situated at about level with the anterior eye-corners.

### Genus Tabanus Lin.

Except for occasional references to the eyes on a species being green (red on *T. cyaneus* Wied.),* there are no records yet made concerning eye-marks on

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Australian species and I myself have manuscript notes in only two cases. There is a considerable difficulty met with in identifying species, and there is no unanimous opinion concerning the interrelationship between species. Ricardo made a number of groups that failed to hold. The hairy eye, as against the bare eye, is about the last of these characters used. White indicated his ideas by suggesting one hairy-eyed species is allied to a bare-eyed species that also has the very long and narrow frons, and this is the first suggestion that breaks away from the traditional scheme. It is proposed here to follow this lead, as it certainly helps in the natural grouping of species.

Already I have grouped into order those species known from Tasmania, where only hairy-eyed forms occur, and here I extend this section in order to incorporate the mainland forms. Most bare-eyed species seem to conform to one or other of those groups already formed, and some groups previously suggested are now reduced by amalgamation. These main features are to be recognized in the following key, the exceptions being few and perhaps not particularly important if the key be used only as a guide.

*Key to sections in genus* Tabanus.

| | | |
|---|---|---|
| 1. | Frons very narrow and parallel-sided | Section 1 |
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| 2. | Frons diverging towards antennae | Section 2 |
| | Frons parallel-sided | Section 3 |
| | Frons converging towards antennae | Section 4 |

## Section 1.

### *Tabanus avidus*-group.

This new group contains inter-related species, including: *Tabanus alternatus* Ferg. & Hill (with synonyms *limbatinervis* Macq. and *macquarti* Ric., both names preoccupied), *T. avidus* Bigot (with synonyms *fuscipes* Taylor and *taylori* Austen), *T. davidsoni* Taylor, *T. doddi* Taylor (with synonym *abstersus* Taylor, nec Walker), *T. duplonotatus* Ricardo (with synonym *parvicalosus* Tayl., nec Ric.), *T. ochraceoflavus* Ferg. & Henry, *T. palmensis* Ferg. & Hill (with synonym *nigropicta* Macq. preocc.), *T. sanguineus* Bigot, *T. torresi* Ferguson, *T. victoriensis* Ricardo and var. *heroni* Ferguson, var. *wentworthi* Ferg. & Hill.

The two varieties are regarded as such by Ferguson, who reduced their rank, but the matter is by no means assured yet. All these are without the appendix, and agree in the frons, antennae and general characters. From others that I have seen (unidentified) and from various descriptions, I suspect several more names will fall here.

Nearest to this group, amid the hairy-eyed species, comes the *Tabanus microdonta*-group, of which only one species is known and is limited to Tasmania. It is not possible at present to draw a limit to section 1, so I cannot tell with certainty if this will come here, but White thought it should be included with *T. victoriensis* Ric.

## Section 2.

This contains the *gentilis*-group, the *gregarius*-group and the *regisgeorgii*-group, all of which seem likely to maintain their status. All species so far placed in them have hairy eyes.

## Section 3.

The *exulans*-group seems to be the hardest to understand and contains the species most confused in literature; the limits are uncertain as they verge towards section 2, but with this paper the hairy-eyed species are now fairly well isolated.

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## Section 4.

The *Tabanus pallipennis*-group is a new one and is well isolated from the other sections and apparently it is the outskirts of a palaearctic fauna, whilst the other three are apparently limited to the Australian region or almost so. As far as I know, this is the only group in Australia that has banded eyes, all others seem to have entirely green eyes except *T. cyaneus* Wied., which is said to have red eyes.

*Key to species of* Tabanus *with hairy eyes.*

1. Fourth radial vein without an appendix, frons rather narrow (*microdonta*-group) .... ..... *microdonta* Macq.
   Fourth radial vein with an appendix. Frons not more than four times longer than wide, usually much less ..... 2
2. Frons of female diverging towards antennae, normally becoming there one and a half times wider than at vertex ..... 3
   Frons of the female parallel-sided ..... *exulans*-group ..... 5
3. Thorax with well-defined dark stripes, four anteriorly and three posteriorly on a grey ground ..... *regisgeorgii*-group
   Thorax with rather ill-defined markings on dorsum, two to five light thin stripes on a dark ground ..... 4
4. Thorax with a median light stripe normal, but sometimes very obscure if not quite obsolete. Wings spotted ..... *gentilis*-group
   Thorax never with the median stripe, wings without spots (*gregarius*-group) ... 13

*Key to the* exulans-*group.*

5. Callus absent ..... *adelaidae* Ferguson; *pseudobasilis* Tayl.
   Callus not reaching eyes, being separated by a pulverulent strip ..... 6
   Callus reaching eye-margins ..... 8
6. Body covered with a uniform pulverulent overlay, brownish-yellow (sand colour), usually completely hiding the markings ..... *vetustus* Walk.
   Body not so covered, the markings defined ..... 7
7. A somewhat yellowish species from N. S. Wales and Queensland ... *ocultus* Ricardo
   Dark forms ..... *neocirrus* Ric. (Tasm.); *dixoni* Ferg. (Vict.); *geraltonensis* Tayl. (Queensl.); and *postponens* Walker (N. S. Wales).
8. Hairs of frons longer than half the width of frons ..... 9
   Hair of frons short, normal ..... 10
9. Fringe on hind tibiae black (Tasmania) ..... *edentulus* Macq.
   Fringe on hind tibiae white (S. Austr.) ..... *albohirtipes* Ferg.
10. Eyes densely clothed with hairs ..... 11
    Eyes scantily clothed with hairs. Large species with black antennae and dark wings; 15 mm. ..... *innotatus* Ferg.
11. Eyes with brownish pubescence; medium to small species ..... *exulans* Erich.
    Eyes with white pubescence; large species, 15 mm. ..... 12
12. Abdomen black and brown with only a median line of light spots ... *whitei*, n. name
    Abdomen more variegated and broader; with three lines of spots, the outer ones oblique ..... *acutipalpis* Macq.

*Key to the* gregarius-*group.*

13. Callus separated from the eyes by a pulverulent strip. Face broad, eye-margins at an obtuse angle ..... *tasmanicus* Ferg.
    Callus reaching eye-borders ..... 14
14. Costa strongly bordered with fuscous; face broad ..... *gregarius* Erichs.
    Costa not so bordered, clear ..... 15
15. Hair on frons and below callus, unusually long and abundant ..... 17
    Hair on frons normal, that below callus short, scanty or absent ..... 16
16. Callus short, not reaching half-way up frons ..... ..... *hobartensis* White (Tasm.); *indefinitus* Taylor (N. S. Wales); *moretonensis* F. & H. (Queensl.) and possibly *milsonensis* F. & H. (N. S. Wales)
    Callus reaching beyond half length of frons .... *imperfectus* Walk (Tasm.); *flindersi* Ferg. (Flinders Is.); *cirrus* Ricardo (Queensl.) and *dubiosus* Ric. (Queensl.)

## Section 4.

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   Body not so covered, the markings defined ..... 7
7. A somewhat yellowish species from N. S. Wales and Queensland ... *ocultus* Ricardo
   Dark forms ..... *neocirrus* Ric. (Tasm.); *dixoni* Ferg. (Vict.); *geraltonensis* Tayl. (Queensl.); and *postponens* Walker (N. S. Wales).
8. Hairs of frons longer than half the width of frons ..... 9
   Hair of frons short, normal ..... 10
9. Fringe on hind tibiae black (Tasmania) ..... *edentulus* Macq.
   Fringe on hind tibiae white (S. Austr.) ..... *albohirtipes* Ferg.
10. Eyes densely clothed with hairs ..... 11
    Eyes scantily clothed with hairs. Large species with black antennae and dark wings; 15 mm. ..... *innotatus* Ferg.
11. Eyes with brownish pubescence; medium to small species ..... *exulans* Erich.
    Eyes with white pubescence; large species, 15 mm. ..... 12
12. Abdomen black and brown with only a median line of light spots ... *whitei*, n. name
    Abdomen more variegated and broader; with three lines of spots, the outer ones oblique ..... *acutipalpis* Macq.

*Key to the* gregarius-*group.*

13. Callus separated from the eyes by a pulverulent strip. Face broad, eye-margins at an obtuse angle ..... *tasmanicus* Ferg.
    Callus reaching eye-borders ..... 14
14. Costa strongly bordered with fuscous; face broad ..... *gregarius* Erichs.
    Costa not so bordered, clear ..... 15
15. Hair on frons and below callus, unusually long and abundant ..... 17
    Hair on frons normal, that below callus short, scanty or absent ..... 16
16. Callus short, not reaching half-way up frons ..... ..... *hobartensis* White (Tasm.); *indefinitus* Taylor (N. S. Wales); *moretonensis* F. & H. (Queensl.) and possibly *milsonensis* F. & H. (N. S. Wales)
    Callus reaching beyond half length of frons .... *imperfectus* Walk (Tasm.); *flindersi* Ferg. (Flinders Is.); *cirrus* Ricardo (Queensl.) and *dubiosus* Ric. (Queensl.)

17. Face excessively wide, the eye-margins lying at an obtuse angle one to the other .... ..... *neolatifrons* Ferg.
Face normal, the eye-margins lying at an acute angle one to the other (belongs to the *exulans*-group) ..... *edentulus* Macq.

Species not known to me are placed in the above key in accordance with their descriptions, but many species require a closer investigation with a view to improving upon the characters here used.

### Tabanus microdonta Macq.

Macquart, 1847; Walker, 1854; White, 1915; Ricardo, 1915; and Hardy, 1934.—*T. wynyardensis* Hardy, 1916 and 1935.

It seems that the form *wynyardensis* is based on unusually small specimens of *microdonta* males. The differences are not apparent and an attempt to find females of the former has yielded, so far, only females of the latter. On this account it is best, I think, to accept the synonymy.

### Tabanus acutipalpis Macquart.

Macquart, 1838; Walker, 1854; Ricardo, 1915; Ferguson, 1921; Hardy, 1934.—*T. circumdatus* var., White, 1915.

The specific interpretation was given by Ferguson, but the synonymy is new.

### Tabanus whitei, new name.

*T. circumdatus* White, 1915; Ferguson, 1921; Hardy, 1934.—nec Walker, Ricardo, etc.

White used the name *circumdatus* under circumstances still obscure. Apparently Ricardo had already fixed the name correctly for a mainland species, followed by Ferguson and Henry, and this is the sense in which it is still used for mainland specimens. However, finding *circumdatus* and its supposed synonym *edentulus* were used by White for two species in Tasmania, the other authors tried to divide the *circumdatus* known to them into two, which has proved impossible. Actually White gave no evidence to show that *circumdatus* proper occurs in Tasmania; the form he called *edentulus* should have been given the name. Ferguson has already shown that *edentulus* used by all authors is wrongly applied and that this should be applied to an ally which is otherwise without a valid name, but to which White applied Walker's name *antecedens*. This synonymy is very involved, but its present elucidation has the advantage of bringing back the naming of species to alignment with the point at which confusion arose subsequent to the clearing up of specific identities by Ricardo and Ferguson. The *circumdatus* of White is without a valid name, and it certainly does not correspond with any specimens well known on the mainland as *circumdatus*. For this reason I have found it necessary to give a new name to White's species, which is limited to Tasmania.

### Tabanus edentulus Macq.

Macquart, 1845; Walker, 1854; Ricardo, 1915; nec White, 1915.—*T. antecedens* Walker, 1854; White, 1915; Ricardo, 1915; ? Taylor, 1916 and 1918; Ferguson, 1921; nec Walker, 1848.

Walker originally described *antecedens* from mainland specimens, and hence it cannot be the form so called by White, which is limited to Tasmania. Walker's second description from a Tasmanian specimen may apply. Ferguson considered that *edentulus* Macquart applies here and, as it seems the only name valid for the species with strong evidence for its validity, I propose the interpretation should be accepted.

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The structure of the frons makes its position in a section rather ambiguous. The frons varying from diverging to parallel does not form an index to its relationship. Other characters show it belongs to the *exulans*-group, but it is placed also under the *gregarius*-group as a convenience for key purposes.

### Tabanus exulans Erichson.

Erichson, 1842; Walker, 1854; Ricardo, 1915 (*esculans*); Hardy, 1935—*T. hebes* Walker, 1848.—*T. nepos* Walker, 1848.—*T. circumdatus* Walker, 1848; Ricardo, 1915, 1917; Taylor, 1918, 1919; Ferguson and Henry, 1919; Johnston and Bancroft, 1920; Ferguson, 1921; nec White, 1915.—*T. abstersus* Walker, 1850; Schiner, 1868; Austen, 1914.—*T. fraterculus* Macq., 1850.—*T. brevidentatus* Macq., 1855.—*T. edentulus* White, 1915; Ricardo, 1915; Taylor, 1917, 1918; Ferguson and Henry, 1919; Ferguson, 1921; nec Macquart.

The above synonymy incorporates that given for the species by Ricardo, but there is doubt if the species incorporated by the various authors include only the one form.

### Tabanus neocirrus Ricardo.

Ricardo, 1917, 1921; Hardy, 1934; nec Ferguson.—*T. bassii* Ferguson, 1921; Hardy, 1934.

The synonymy is new and the confusion here originates from Ricardo having quoted Tasmania as the type locality, but Ferguson considered she described from two species, the type being that from South Australia. Apparently Ferguson redescribed the species from Victoria, including in it the same species from Tasmania as Ricardo's, if the type locality given by her is to be accepted.

In my earlier paper I attempted to deal with these as two species, a position that cannot be retained. The Tasmanian record of *T. bassii*, which specimen is before me, is only a specimen of *neocirrus* with a very denuded abdomen, and the narrower frons that seemed apparent is only a specific variation; careful study shows it to be of the broad type normal to the species. Doubtless the mainland specimens in Ferguson's small series have the same type of denudation. It has yet to be discovered if the South Australian specimen of *neocirrus* is distinct, and it is pertinent to note that Ferguson regarded the Tasmanian series of *neocirrus* before me as containing two forms.

### Tabanus imperfectus Walker.

Walker, 1848, 1854; White, 1915; Ricardo, 1915; Taylor, 1918; Ferguson, 1921; Hardy, 1934.—*T.* species, near *imperfectus* Ferguson and Henry, 1919.

I have a mainland specimen identified by Ferguson as being *T.* sp., near *imperfectus*, but it differs from the Tasmanian specimens only in the less dense pubescence of the eyes, a specific variation. One Tasmanian specimen has the frons parallel-sided.

### *Tabanus pallipennis*-group.

Section 4, consisting of a large element in the Palaearctic region, seems to be limited in Australia to a single group containing only two species as far as yet known. Of these *T. pallipennis* Macq. was seen by neither Ricardo nor Ferguson, but the latter used the name for a species with spotted wings, which is normally met with in inland districts. The original description makes no mention of the wing spots and hence can be applied quite readily to *rufinotatus* Bigot and may ultimately be found to belong there.

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The group is characterized by the converging frons with two calli, the second lying above the normal one and formed into a round spot; the two may join on abraded specimens by a median line. The abdomen has three almost equally broad light stripes more or less interrupted at incisions, and both species have eye-marks.

TABANUS PALLIPENNIS Macquart.

In life the eyes of the female have a green band at antennal level and another above lower callus level. This gives one red band situated at callus level lying between two green bands and two red blotches.

The contiguous eyes of the male have an abnormal marking. The upper blotch is grey-black and below this lies a white band that persists after death, and it touches the anterior eye-corners where the band is broadest, tapering towards the posterior border, ending in a point before reaching there. Below this is a purple band. The lowermost area covering the antennal level is green. That white band is apparently a layer of opaque white at or near the surface, not arising from ordinary eye-pigmentation; it extends across the two eyes as an uninterrupted band.

*Hab.*—Victoria to Queensland. Widely distributed over the inland sheep areas, recorded from Lake Hatton, reaching to Gogango, about thirty miles west of Rockhampton. The specimens upon which the eye description is based are from Goondiwindi, about four miles north of the township; 5 ♂, 3 ♀, September, 1935.

TABANUS RUFINOTATUS Bigot.

Eye-marks of the female only are known to me. This sex has a green band at antennal level and another just half-way between this and the summit, so that one red band lies at and below callus level between two green bands and two blotches, giving a pattern very similar to that of the previous species. The fly is common in Brisbane.

THEREVIDAE.

*Chaetotaxy.*—White refers to the bristles of the thorax as being presutural, supraalar, postalar, prescutellar and scutellar, whereas Mann refers to them as prealar, supraalar, postalar, prescutellar and scutellar. Relative to those of the Asilidae, there are notopleural, presutural, intraalar, postalar, postsutural, dorsocentral and scutellar bristles. There are no supraalar bristles and the so-called prealar often combine the notopleural with the presutural one.

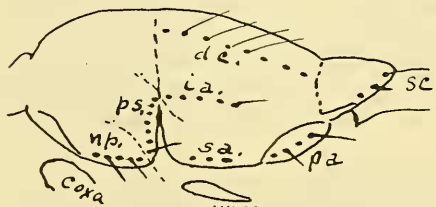


*Diagram of chaetotaxy.*

This diagram combines the bristles normal on a Therevid with more abundantly represented bristles (dots) on certain Asilidae. *dc*, dorsocentral bristles; *ia*, intraalar bristles; *np*, notopleural bristles; *pa*, postalar bristles; *ps*, presutural bristles; *sa*, supraalar bristles; *sc*, scutellar bristles.

The diagram (Fig. 1) shows rows of dots representing the line of bristles in Asiloidea and the reduced number of bristles represented on Therevidae are drawn in full. The row *np* lying along the notopleural ridge is confluent with the row *ps* that borders the transverse suture, and this again is confluent with the intraalar row *ia*. These rows are normally reduced in regard to number of bristles on most Asilidae and all Therevidae. The dorsocentrals, when present, are usually over the central portion of the postsutural region, less frequently in the immediate prescutellar region on Therevidae.

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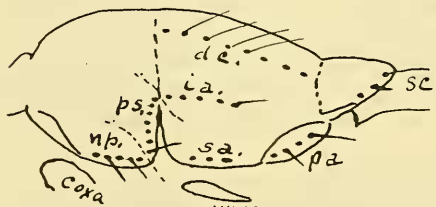


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ECTINORRHYNCHUS VARIABILIS Macq.

On the eyes of both sexes there is only an upper blotch of red; the green at antennal level and below invades this red along the eye-margins, producing a rounded red blotch. This description is based on Brisbane specimens, but an old Tasmanian specimen was used, not very satisfactorily, in an attempt to revive the colours, and this showed traces indicating that the same marking occurs there.

ECTINORRHYNCHUS LEVIS Mann.

The eyes are entirely red on the male, those of the female have not yet been noted.

TAENOGERA NOTATITHORAX Mann.

The eyes of the female are uniformly but obscurely greenish shot with red. The male of this fly is unknown.

NEODIALINEURA STRIATITHORAX Mann.

The greenish-yellow eyes of the female have a red complete band just above antennal level, and in addition the lowermost eye-border is margined red. The markings on the male are not yet noted.

AGAPOPHYTUS RUFICAUDATUS Mann.

The eye on the female has a green band at antennal level with a red band below and a large red blotch above; the rest is green.

AGAPOPHYTUS ALBIBASIS Mann.

The green eye on the female has a green band at antennal level bordered by a red band above and below. The upper red band strongly tends to become thin at anterior margin and the lower one broadens out there; otherwise the bands are fairly uniform in width.

The male is similarly marked, but the upper band is very sinuous and does not reach the posterior eye-margin, whilst the green band is thereby rendered irregular in width.

AGAPOPHYTUS SQUAMOSUS Mann.

The red eyes of the female have four green bands all reaching the eye-margins. The uppermost green band is broad and curves upwards at each end. The second and third bands are similarly curved and it is uncertain which is to be regarded as being at antennal level; they fuse together along the posterior eye-margin. The lowermost band lies practically straight and at a level half-way down the face.

ACUTIPALPA POLINOSA Mann.

*Synonymy.—A. semiflava* Mann.

Associated with *A. polinosa* Mann, only recorded on the male, there are invariably found females that correspond with *A. semiflava* Mann, only recorded on the female. These have not yet been taken *in copula*, but field evidence is very strong on the suggestion that they are sexes of the same species. I have a letter from Mr. Mann, in answer to this, saying that he too has suspected the names belong to the one species. This dimorphism is a feature of the genus, so doubtless the synonymy is quite correct.

On the male the eye has a green band at antennal level, but the green invades upwards along the eye-margins, isolating the large red area above into a spot. This large triangular spot has a concave anterior side and a convex posterior side with a moderately straight base. Below the green band is a red one which reaches

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both eye-margins, and the lowermost border of the eye is margined with red, a remnant of the blotch. Elsewhere the eyes are green.

The female has a very similar design, but the green at antennal level does not extend as far as the summit, so the red triangular area maintains contact with the eye-margin, thus retaining the character of a blotch. This blotch is similar in shape to the spot on the male, but with the top of the triangle cut off by the eye-margin. The red band below does not reach the posterior eye-margin and the whole area below this is green.

### Acraspiza obscuripes Mann.

I have only seen the characters of the eye on one male and two females, and my notes were not made with reference to the new species below. From my notes it would appear that the male has a green band at antennal level lying between two red bands; the area above is reddish, and that below is green. The female has a green band at antennal level lying between a red blotch above and a red band below, the band not reaching the posterior eye-border. These remarks are based upon specimens taken at Sunnybank close to where the type pair were taken *in copula*.

### Acraspiza similis, n. sp.

Subsequent to the publication of *A. obscuripes*, and taken in the same place, a new species has been discovered that at first was thought from males only to be the same. Recently the discovery of a pair *in copula* has shown very decisively that there are two species standing in collections under the name *obscuripes* male, but this does not affect any of the type series in accordance with information given to me by Mr. Mann.

♂. Very similar to *obscuripes* Mann, but of larger average size. The eyes have a green band at antennal level, between two red bands; the upper red band is turned upwards near the posterior margin, which it does not reach, and the lower red band fails (? not always) to reach the posterior border too. Above this the eye is reddish or at least shot with red, and below it is green. The facets above are strongly contrasting with those at and below antennal level, with a marked line of division, which character is less marked on *A. obscuripes*. The two basal segments of the antennae are equally short. The thorax each side of the median line has 2 notopleural, 3 presutural dorsocentral, 1 intraalar and 1 postalar bristles; and a pair of scutellar marginals. The black abdomen shows brown integuments at the base and at some incisions. The yellow hypopygium and legs (including coxae) are further distinctive characters, as also the wing pattern, which is hardly reduced, but resembles that of the female on both this and *obscuripes*.

♀. A green band at antennal level lies between a red band below and a red blotch above; the latter does not reach the posterior eye-margin; elsewhere green. The frons is fully twice as long as its median width and hence is obviously narrower than that on *obscuripes*. The thorax is quite bright reddish instead of deep reddish-brown, and there are only two dorsocentral bristles. The abdomen has a slight covering of tomentose brown above, otherwise all characters are as on the male.

*Hab.*—Queensland: Brisbane, the holotype male and allotype female *in copula*, 7 ♂, 8 ♀ paratypes all captured at Sunnybank, April, 1937 and 1938, by sweeping grass. Others in September, October, February, March, and May, 1930, 1933, 1936 and 1937, so doubtless the species is quite common over the summer months.

both eye-margins, and the lowermost border of the eye is margined with red, a remnant of the blotch. Elsewhere the eyes are green.

The female has a very similar design, but the green at antennal level does not extend as far as the summit, so the red triangular area maintains contact with the eye-margin, thus retaining the character of a blotch. This blotch is similar in shape to the spot on the male, but with the top of the triangle cut off by the eye-margin. The red band below does not reach the posterior eye-margin and the whole area below this is green.

### Acraspiza obscuripes Mann.

I have only seen the characters of the eye on one male and two females, and my notes were not made with reference to the new species below. From my notes it would appear that the male has a green band at antennal level lying between two red bands; the area above is reddish, and that below is green. The female has a green band at antennal level lying between a red blotch above and a red band below, the band not reaching the posterior eye-border. These remarks are based upon specimens taken at Sunnybank close to where the type pair were taken *in copula*.

### Acraspiza similis, n. sp.

Subsequent to the publication of *A. obscuripes*, and taken in the same place, a new species has been discovered that at first was thought from males only to be the same. Recently the discovery of a pair *in copula* has shown very decisively that there are two species standing in collections under the name *obscuripes* male, but this does not affect any of the type series in accordance with information given to me by Mr. Mann.

♂. Very similar to *obscuripes* Mann, but of larger average size. The eyes have a green band at antennal level, between two red bands; the upper red band is turned upwards near the posterior margin, which it does not reach, and the lower red band fails (? not always) to reach the posterior border too. Above this the eye is reddish or at least shot with red, and below it is green. The facets above are strongly contrasting with those at and below antennal level, with a marked line of division, which character is less marked on *A. obscuripes*. The two basal segments of the antennae are equally short. The thorax each side of the median line has 2 notopleural, 3 presutural dorsocentral, 1 intraalar and 1 postalar bristles; and a pair of scutellar marginals. The black abdomen shows brown integuments at the base and at some incisions. The yellow hypopygium and legs (including coxae) are further distinctive characters, as also the wing pattern, which is hardly reduced, but resembles that of the female on both this and *obscuripes*.

♀. A green band at antennal level lies between a red band below and a red blotch above; the latter does not reach the posterior eye-margin; elsewhere green. The frons is fully twice as long as its median width and hence is obviously narrower than that on *obscuripes*. The thorax is quite bright reddish instead of deep reddish-brown, and there are only two dorsocentral bristles. The abdomen has a slight covering of tomentose brown above, otherwise all characters are as on the male.

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*Note.*—The scutellum in this genus is said to be raised to the perpendicular, but actually this is not morphologically comparable with that of any other genera examined where the apex of the scutellum lies considerably higher than the base. In the present case there is the apex with its apical bristles quite normal, but the dorsal surface of the scutellum has a large protuberance rising perpendicularly, giving to the observer the impression of a raised scutellum.

ACRASPIZA TRIFASCIATA Krober.

There is a male before me that evidently belongs to this species, and it bears on its label "Bred from a Scenopinid ? larva" and on another label "Gordonvale, W. C. Dormer, 19.10.23". It may be presumed, I think, that this fly was reared from an Asiloidean larva. All Therevid larvae that I have found have been living free in the soil. Melin has pointed out that Asilid larvae may be reared on a vegetable diet, and, with my own experience, which is limited, I find field observations suggest that the carnivorous habits are not essential for the Asiloidean larvae; it is possible they are omnivorous, feeding in an incidental manner on any other larvae that may be associated with them.

*Addendum.*

ON EYE-COLORATION.

Whilst writing the above paper I briefly set down some ideas on eye-coloration and sent them to Dr. B. M. Hobby, of the Oxford University. I expected the main theme would interest him and others who are also collecting in the field data concerning insect behaviour. Dr. Hobby forwarded the manuscript to Dr. H. Eltringham, of Stroud, Gloucester, an authority on related matters, and received in reply an encouraging letter which is now before me.

Dr. Eltringham has since then allowed me to quote from his letter and a subsequent one. He informs me it had not occurred to him that there is any connection between the colour of insect eyes and their habits, but it is ". . . an interesting point that might be worth investigation . . ." "Red and black in flies' eyes are due to colour of the pigment surrounding the pseudocones, red being much the commoner." "So far as I have been able to make out, green is always a 'structural' colour caused by iridescence. The fact that there are these green eyes would, however, suggest that there is some difference in the structure. . ."

The letters then discuss Exner's original paper, which goes somewhat elaborately into refraction from the mathematical point of view, and which Dr. Eltringham found to be unusually obscure. In 1933, Dr. C. J. Van der Horst published a paper on the optics of the Eucone eye, purporting to show that the existing theories in relation to this type of eye are untenable. The point was submitted to Mr. T. R. Smith, of the National Physical Laboratory, and in his opinion Van der Horst's conclusions are invalid, since the optical principles invoked are not applicable to the structure in which the elements are in physiological continuity.

Dr. Eltringham, in his first letter, expressed the opinion that if the green colour be a diffraction effect, and due to interference by some structure of smaller dimensions than the average light wave, there seems little hope of detecting it in a micro-section, and he ends on the encouraging note: "At the same time let Hardy carry on. His results should be very interesting, but I should recommend him to get a lot more data before publishing."

It will be many years before my limited opportunities for field work can bring results. The study is, of course, of basic interest and without it insect

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behaviour cannot be adequately understood. I am indebted, however, to both Dr. Hobby and Dr. Eltringham for having cleared up the exact position relative to the theory of eye-colour in insects. Tentatively my theory stands that green is entirely due to refraction or some allied displacement of light, a structural alteration. This is slowly taking place parallel with alterations in behaviour, giving a new sense to or an improvement to vision in the Diptera. This is, however, only one branch in the study of coloration relative to the insect's welfare, and I have further notes that trend towards showing the development of body-coloration coming more or less under the studies in so-called "mimicry". Parallel developments in body-coloration and form are well known, but hitherto I have seen no data or theories to indicate how these convergences have been brought about. The purpose of the above paper and others in manuscript is to accumulate data rather than to express a theory, data that may clear up an obscure point relative to eye-coloration, namely, whether this has relationship to fly behaviour.

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